Mobile Human Computer Interaction

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Introduction

Mobility

Characteristics of a mobile device

- Small
- Attractive designs
- Lightweight
- Limited battery capacity
- Limited network bandwidth?
- Limited quality of service (network)
- Small displays
- Small and reduced keyboards

Characteristics of a mobile user

- In a hurry
- On the move
- Doing several things simultaneously
- Stressed and or anxious
- Impatient

Characteristics of the environment

- Noise
- Undesireable lighting conditions
- Limited freedom of movement
- Mechanical disturbances
- In change

Characteristics of a mobile task

- Simple
- Short duration
- Single

What is a mobile device?

- Mobile phone
- PDA's
- Laptop computers?
- Wristwatches?
- Pocket calculators?
- Pocket translator?
- MP3-players?
- Portable game consoles?
- Wireless things?
- Are there others???

What is the best input device?

Analogies to toys

Which one is the best?

- A: Drawing a rectangle

- B: Handwriting
- *Writing is fun*

Does this change anything?

ACTIVITY: design a text entry strategy

- Assume you are to program a miniature device with three keys and a display.

- Outline a strategy for entering ASCII text using this device (general concept)

What was the rationale behind your design? (Why is your design good?)

Evaluation criterias

Evaluation criterias

- How fast are they to use?
- How easy is it to learn?
- How easy is it to use?
- How easy is it to fix errors?
- Possibilities of editing the text?
- Adding other characters?
- Feedback dependence?
- Skill transfer

Typing speed

- Obtained from measurements through experiments
  - Words per minute
    - 5 characters per work+space
  - Characters per minute
  - Average inter-keystroke delay

KSPC

- Keystrokes per character
  - Minimum KSPC
  - Maximum KSPC
  - Average KSPC

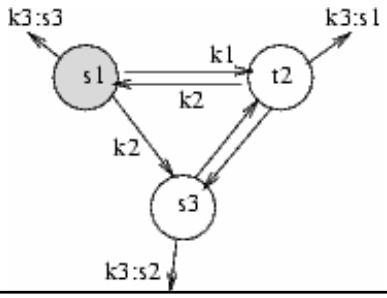
$$\overline{KSPC} = \sum KSPC(x)\,p(x)$$

  - Theoretical estimate of effort involved
  - Is it realistic?

A tiny digression: using graph theory as an evaluation tool

Comparing strategies using graphs

- Uniform representation of static text entry strategies
  - Vertices represent states
  - Edges represents transitions
  - Labels indicate:
    - Triggers
    - Outputs



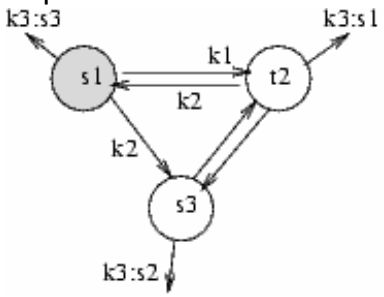
What can we do with the graph?

- Uniform way of representing text entry strategies
- Compare different strategies
- Compute KSPC
- Check that a design is valid
- Check for error recoverablilty
- Compute other measures such as cognitive factors.
- Use tools to help us do the work

End of digression

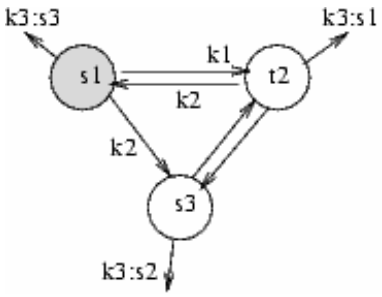
Computing KSPC from a graph

- Follow the paths to produce the different characters
- Count the number of triggers (edges) on the path



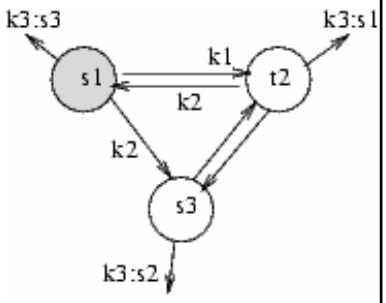
Checking that a design is valid

- Coverage: have we included the entrire alphabet of symbols in the design
  - A simple scan of the graph
- Reachability:can we reach all the output producing transisitons from the start state
  - Walking the graph



Can we correct errors?

- Is there a path from any reachable state to all the output transitions?
- How much effort is involved in correcting errors?



Editing text and special characters

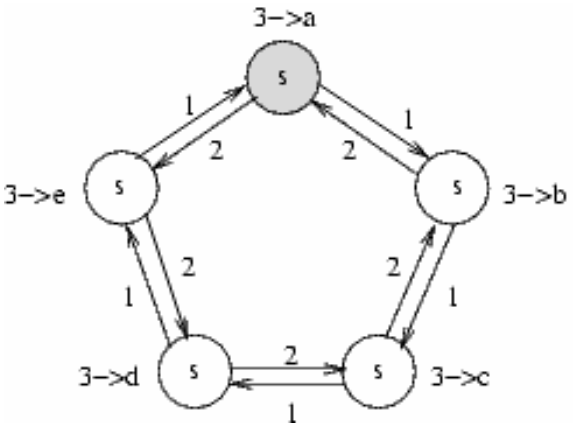
- Look for the presence of the desirable output symbols, i.e. +, -, (,), 0, 1, 2, .., 9 etc.
- Look for the presence of editing symbols
  - Up, down, left right
  - Backspace and or delete
- How to change case?
  - Case state modifier
- Most research papers omit these important aspects of a design.

”Eyes free” interaction

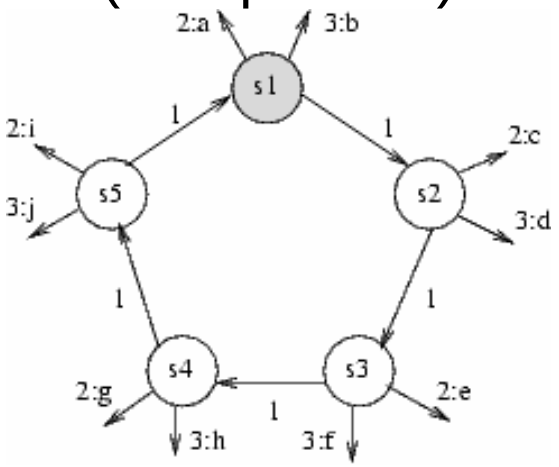
- Interfaces that can be used without visual feedback
- Properties
  - Conduct multiple tasks simultaneously (drive a car)
  - Possibility of accelerated text entry
  - Only possible with static interfaces
  - Requires a simple cognitive model representing the text entry procedure

Possible solutions

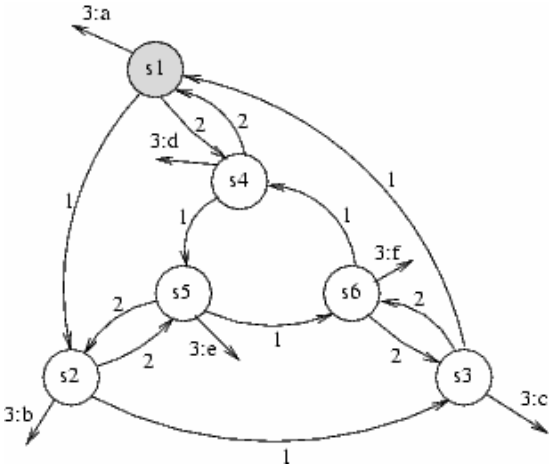
Date stamp (simplified)



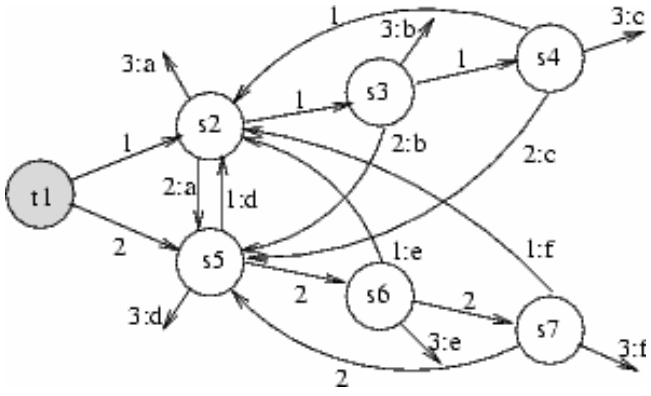
Modified date-stamp (simplified)



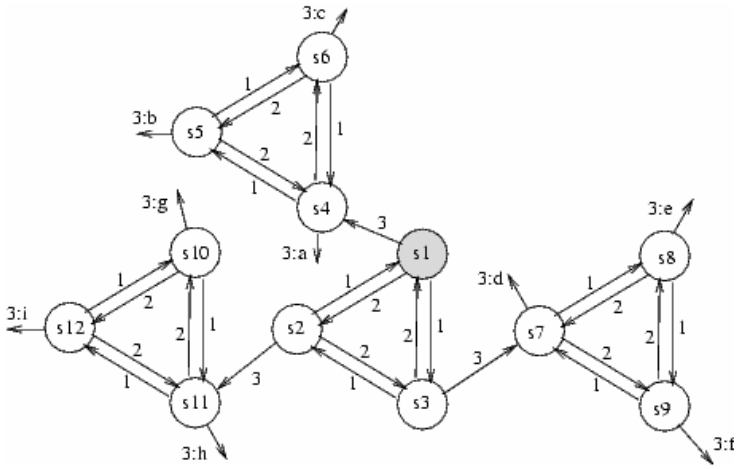
Wristwatch strategy (simplified)



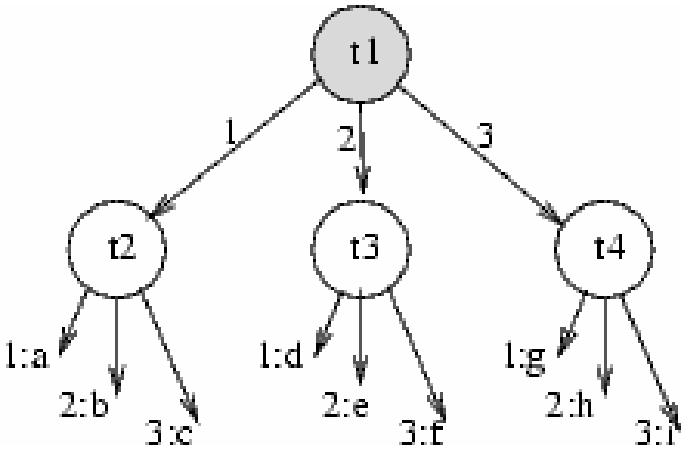
Mobile phone multitap (simplified)



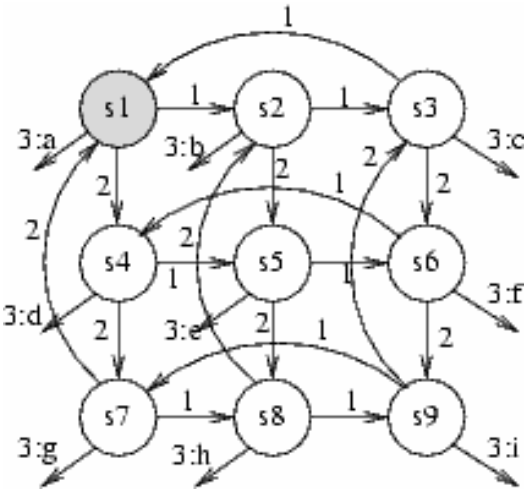
Multi-ring (simplified)



Tree-based (simplified)



Mesh (simplified)



Two main types of input controls

- Space Multiplexing: in which each function to be controlled has a dedicated transducer.
- Time Multiplexing: in which one device is used to control different functions at different points in time.

Space multiplexing

- Little confusion regarding the function being executed.
- More training required
- Expensive
- Require large real-estate
- For static layouts – motor memory can be used to locate a control with little visual distraction (QWERTY keyboard, gear-stick)

Time multiplexing

- Highly modal
- Cheaper
- Less real-estate
- Mutual exclusive tasks
- Often feedback is used to reduce confusion
- Tradeoff between time and space multiplexing

Example

- Mouse
  - Calculator
  - Scrollbar
  - Drawing tool
  - Menu selector
  - Game navigation

Tradeoff between time and space multiplexing

- How many devices should we have?
- What should they be?
- Which tasks to assign?

- Display is usually space-multiplexed
- Input is usually time-multiplexed

Cash up front or infinite installments

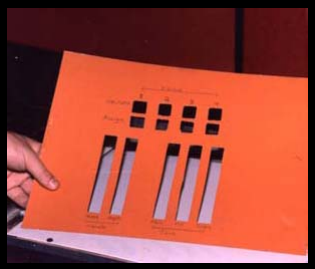
- Save 10 min of training time for system
- Lifetime of inefficiency

Touch tablets

Touch tablets

- Have no mechanical intermediate pieces
  - suitable for public spaces where things get stolen
- The pointer stays put (unlike mouse)
  - Suitable for environments subject to vibrations and motion
- Low profile
  - Can be easily integrated into small portable devices
- Can be molded into one piece constructions
  - Avoid cracks that collect dirt, very clean or very dirty environments
- Simple construction and no moving parts
  - Long life, high reliability, high usage
- No kinesthetic or mechanical restriction for number of touching point
  - Use of multiple fingers, mouse only one point.
- Can use overlaying templates
  - Create physical sensation of ridges of interfaces such as virtual keyboards
- Can be used either in absolute or relative mode
  - Absolute position, relative motion or combination with different regions (templates)

Templates for virtual devices

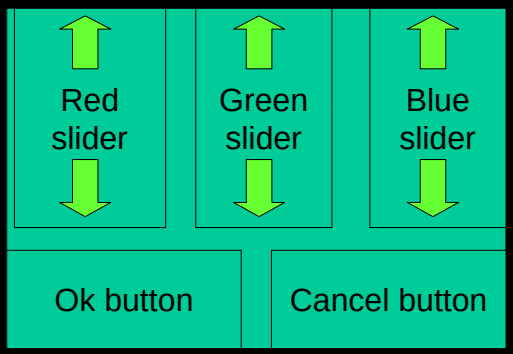


Virtual devices

- One physical device (tablet) simulates multiple virtual devices.
- If concentrated on a small tablet then user quickly learns the layout.
- Can be used without much visual feedback with very little training.

Mixing colours – each region one virtual device

Touch Tabled Real estate



Simultaneous control of multiple devices

- Common to move several controls simultanesouly on mixing desks.
- ..or knobs on a synthesizer
- Possible with multiple contact points

Problems with touch tablets

- Friction on the surface may cause problems over time
  - Especially if the user must apply high pressure on pressure sensitive tablet.
  - Choose good materials, avoid long periods of high pressure manouvres
- Lack of feedback
  - User cannot feel when virtual button is clicked etc.
  - Need for other kinds of feedback (audio or visual)

Future direction for touch tablets

- Commercial version of pressure sensitive multiple point of contact touch tablets.

Cognition and human information processing

Limited resources

- Critical resources
  - Resources needed to execute a task
- Limited resources
  - Resources of limited supply
  - What happens when supply do not meet demand?

Resource utilization of tasks

- The processing resource available
  - Memory, processing cycles and internal communication channels.
  - If adding resource improves performance, then task is resource limited
- The quality of the available data
  - Signal data limits
    - Signal-to-noise ratio (conversation next to a building site)
  - Memory data limits
    - Past experience, world context, relate new situation to old

Improving performance

- Improving performance:
  - Add resources only while resource limited, then improve the quality of available data.
- By improving data,
  - one can reduce resources needed
  - Or improve performance
- Tradeoff between resource utilization and data quality (we usually prefer to use fewer resources)
  - Better graphic design -> better signal data
  - Training and better mental models -> better memory data

Cognitive load

- Cognitive load is a measure of how difficult a task is, or how much resources it consumes.
- Cognitive load is related to:
  - Learning time
  - Fatigue
  - Stress
  - Proneness to error
  - Inability to “timeshare”

Interference

- Some tasks cannot be timeshared (insufficient resources)
  - Talking to two children at the same time
- Some tasks can be performed simultaneously (sufficient resources)
  - Driving and listening to the radio
- Interference is the degradation of one task due to another (insufficient resources)
  - Driving and listening to the radio, while skidding
    - We pay less attention to the radio program while handling the problem.

Reducing interference

- Reduce cognitive load
  - Reduce resource usage
  - Increase data quality
- Reduce chance of resource competition
  - Different sensorary modalities utilize different resources
    - Eg. Change from visual error messages to audio error messages during pointing task.

Problem solving

- Problem solving requires
  - Attention
  - Resources
- Computer related problem solving tasks
  - Functional (the means)
    - How do I insert a diagram here?
  - Behavioral (the content)
    - Should I insert a diagram here?

Assisting problem solving

- Minimize operational problem solving
  - That usually diverts attention away from other things
- Reduce overhead of functional problem solving
  - “representation as a tool of thought”
  - Help the user get to the heart of the problem along the shortest possible path, utilizing a minimum of cognitive resources on the way

Cognitive skills

- Skilled task performance is automatic
- Skilled task performance consumes few cognitive resources compared to problem solving
- Other tasks may be performed synchronously with the skilled task
- An expert can execute two tasks in parallel.

Cognitive skills experiment

- Setting: Eating in Chinese restaurant
- Task: Eating with chopsticks
- Interference:Talking to the various guests
- Observe skill level of:
  - Novice: drops his food once spoken to
  - Some experience: manages to continue but eventually drops his food
  - Expert: continue talking totally unaffected

Skill acquisition

- Cognitive and motor-sensory skills dependent on repeated practice
  - Power law of practice – the more you practice the smaller the improvement.
- Different task highly different learning curves
  - Riding bicycle
  - Playing a violin.
- Controlled training of skill in isolation
  - Isolated skills often transfer and can be used simultaneous to other tasks
- An exciting field in development...

Skill transfer and consistency

- Tradeoff between proficiency and learning curve.
  - Invest in training and gain better performance
- “Easy to use” and “quick to learn” are really reliant on transfer of existing skill
- Any new skill needs to be learned from scratch
- Often we can reuse an existing skill in a new setting.
- A new skill may be able to exploit an existing skill as a point of departure (“know the user”).

Successful skill transfer

- Build upon users' existing set of skills
- Keep the set of skills required by the system to a minimum
  - With few skills, each skill is used more
- Use the same skill whenever possible for similar circumstances
  - Maximize in system skill exploitation.
- Use feedback to effectively reinforce similar contexts and distinguish those that are different
  - Eventually users are able to intuitively infer what to do

Skill transfer examples from text entry: How to make Things work

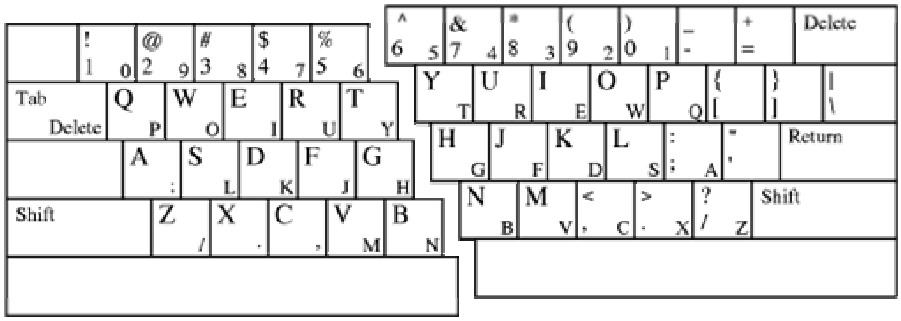
Skill transfer examples

- We can exploit the users' skills:
  - Alphabetical order (Is D before T?)
  - Numerical order (Is 3 less than 7?)
  - From left to right (westerners)
  - QWERTY layout (Is d typed with the left or right hand? What finger?
  - Num-pad layout (Do you remember your pin-code or the finger movement?)

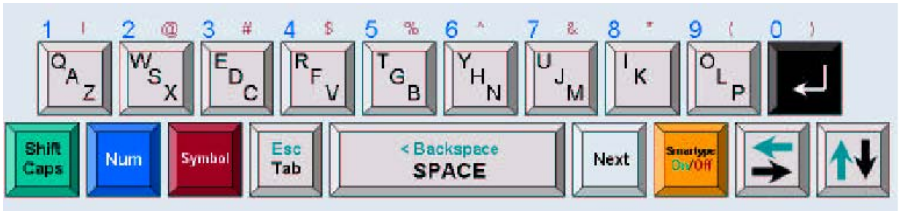
Skill transfer

- Half-QWERTY (commercial success)
- Stick-keyboard (experimental)
- Double-joystick game controller (under development)

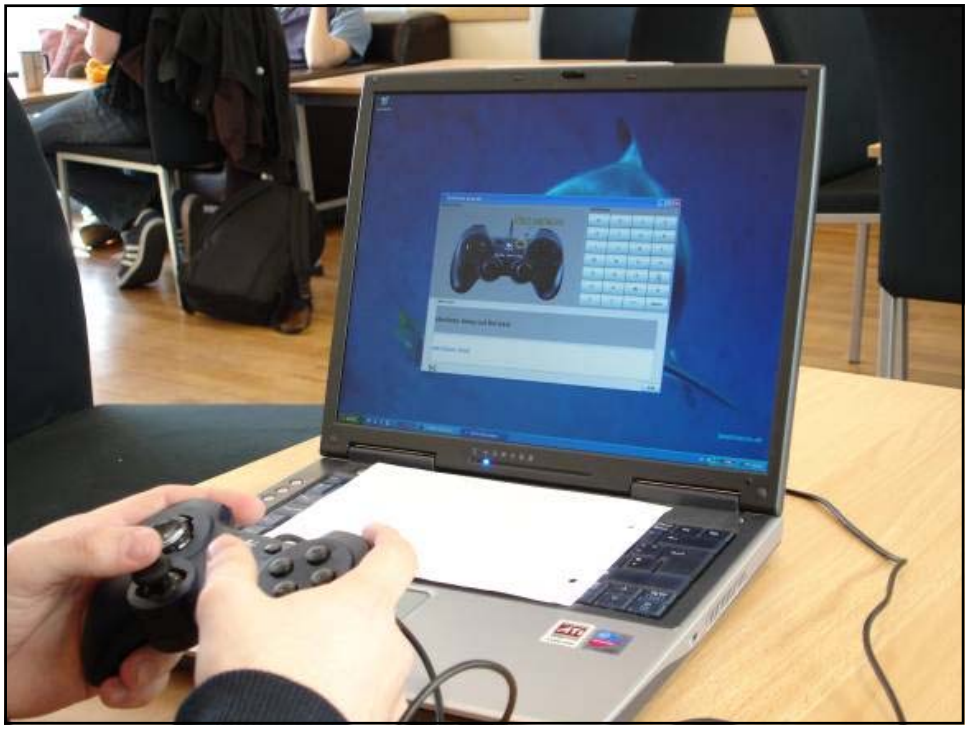
Skill transfer 1: Half-Qwerty (Matias, 1993)



Skill transfer 2: Stick-keyboard



Skill transfer 3: Game-controller (OUC)

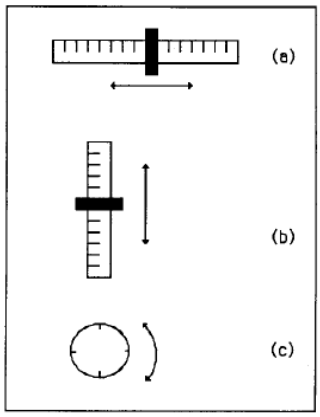


Compatibility

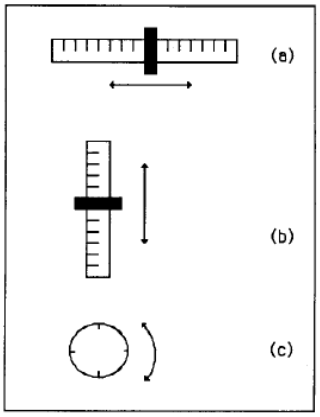
Compatibility

- When the cause-and-effect behavior of a system matches user expectations we have stimulus-response (S-R) compatibility
- High S-R compatibility results in shorter training-learning time and smaller operational load..
- Compatibility driven by
  - Spatial congruence
    - Where you expect to find menu items
  - Custom
    - Which way turn a light-switch to turn on the light (up or down)
      - US up
      - UK down

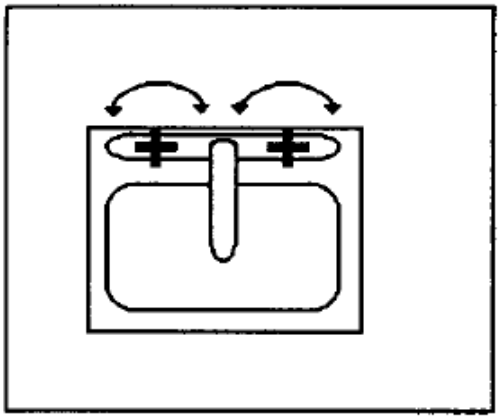
Which direction to increase frequency?



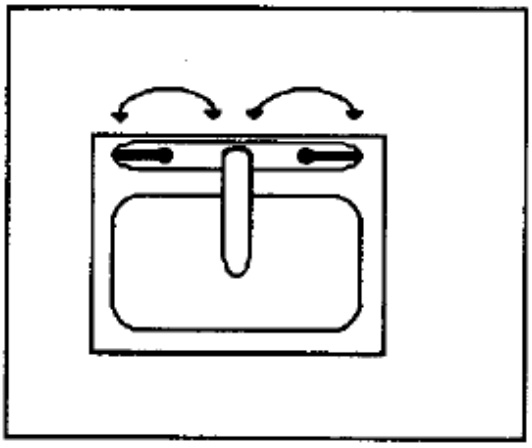
What if the slider represents the period of the signal?



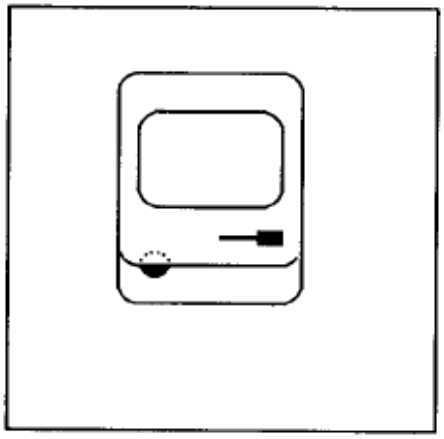
Which know for hot and which for cold water?



How to turn on the water?

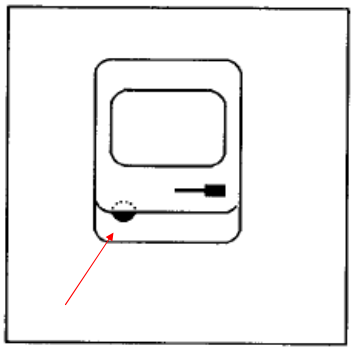


How to increase the screen intensity?



Design mistake?

- In the original Macintosh design a rotating potentiometer was used.
- Usually turning it clockwise to increase
- But mounted upside-down
- Users apply left-to-right to increase (anti-clockwise)



Human performance

Effects of muscle group

- Properties of different body parts directly related to their mass and size
- Fingers, wrists and thumbs (fine muscle groups)
  - High dexterity
  - Small amplitude of displacement
- Arms, elbows, shoulder (large muscle groups)
  - Low dexterity
  - Large amplitude of displacement
- Some studies shows that the wrists provides better performance than the thumb.
- How accurately can be control a mouse?

The biathlon principle

- Tradeoff between micro and macro movements
  - Running:
    - large muscle group
    - Increases heart rate
    - Speed important, reduce overall time
  - Shooting:
    - fine muscles groups
    - Accuracy of motion important
    - Require slow heart rate for good accuraty
    - Adds to overall time
  - Cycle of running and shooting
    - Balance accuracy and speed

Two handed input

Two-handed input

- A student turns the page in a book while taking notes
- A driver changes gears while steering a car
- A recording engineer fades the strings while brining in the drums

Bimanual activities

- Most human activities are bimanual
- Most HCI tasks only uses one hand
  - With the exception of QWERTY typing
- For most HCI tasks we do not exploit skills from lifelong learning, unfortunately.
- Future direction of HCI: exploit bimanual skills

Two handed input

- How do we determine which tasks are suited to two-handed input techniques?
- How do we assign roles to hands?
- Which input devices will be appropriate and how do we design the techniques to maximize their benefits?

Why so little two handed input

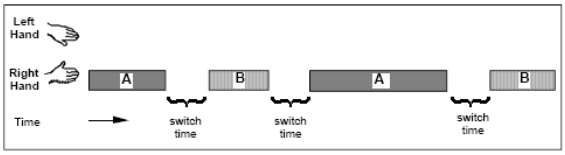
- Technical restrictions – one handed devices (mouse etc)

Temporal properties

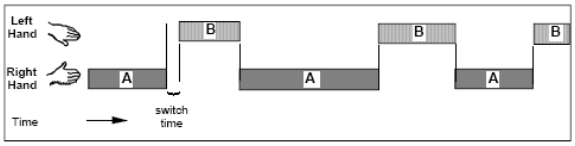
- Task A: Paining
- Task B: Switch to hidden part of canvas canvas
- One handed approach
  - Dominant hand is used to do everything, paint, navigate to menu to hidden part of canvas.
    - Long cognitive delay to switch between painting and navigating
- Two handed approach
  - Dominant hand: paining
  - Non dominant hand: selecting hidden part of canvas (using separate canvas scrolling device)
    - Shorter cognitive delay associated with switching task

Example 1: switching between tasks

- Single handed approach

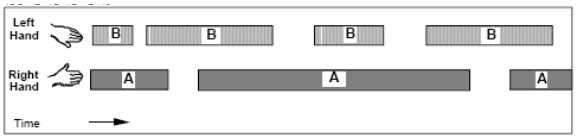


- Two handed approach using

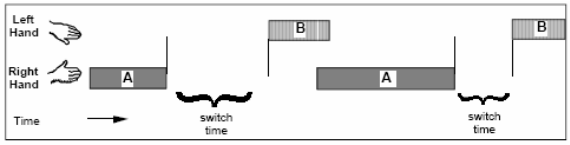


Example 2: exploiting parallelism

– Performing subtask A and B in a cooperative



– Performing subtask A and B in a competitive manner – additional cognitive delay eliminate



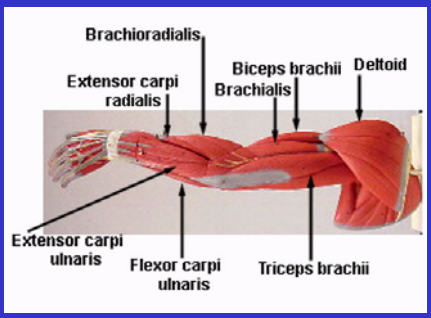
Assignment of tasks to hands

- Loosely integrated tasks
  - Background foreground tasks
- Strongly integrated / tightly coupled tasks
  - Qwerty typing
  - Threading a needle
- Skill acquisition through practice

The kinematic chain

Cooperation within a kinematic chain

- Human body hierarchical structure or cooperative pats
  - Elbow, wrist, fingers
- Between limb
  - Left / right
- Within limb
  - Distal / proximal



Properties of the kinematic chain

- Distal to proximal frame of reference
  - Inertia of movements larger at the proximal side of a joint than the distal side (e.g move wrist)
- Scale hierarchy
  - From distal to proximal joints
  - More distal joints have finer granularity than primal joints
  - E.g. elbow larger movements than fingers

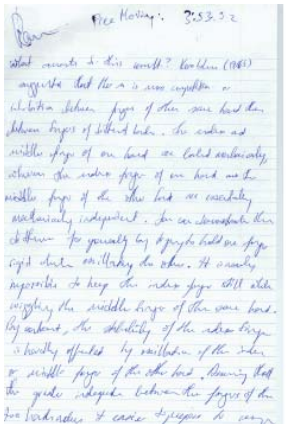
Properties of the kinematic chain

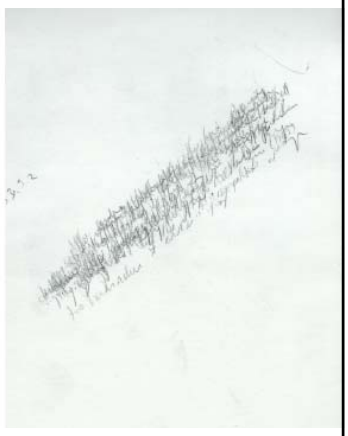
- Proximal precedence - timing
  - From proximal joint to distal joint, although may be overlap
  - first macro movement to reach approximate position (arm), then micro movement for the remaining distance with fingers-----

Two handed collaboration in relation to the kinematic chain

- Principle 1: Right to left hand reference
  - Two handed operation is asymmetric
    - Left hand fixture or support (frame of reference)
    - Right hand main task
  - E.g. Opening a jar
    - Left hand fixture: holding the jar
    - Right hand: doing the actual operation (rotating lid)
  - The role of the left hand often underestimated
    - Is only one hand used for handwriting?

Handwriting task





Handwriting task

- Two kinds of motion
  - Pen, high frequency movements to produce text
  - Paper, low frequency movement to adjust the position of the paper
    - Point of contact with paper is approximately of constant distance to the person writing.
    - Left hand periodically readjust the position of the paper to make it easier to write
- Subjects only allowed to use one hand for handwriting has increasing difficulties.
- Left hand provides the frame of reference for the right hand
  - Motion at a larger spatial-temporal scale

Two handed collaboration in relation to kinematic chain

- Principle 2: Macro- vs. micrometric functional differentiation of the hands
  - Left: Macrometric functions
    - Low frequency operation, coarse grained
  - Right: Micrometric functions
    - High frequency operation, fine grained

Two handed collaboration in relation to kinematic chain

- Principle 3: Left hand precedence or right hand lag
  - Left hand activated before the right hand
  - Left hand provides the point of reference or stabilizing function, before the right hand can start
    - Place the nail on a board before hitting with hammer
    - Microscope, first macro wheel, then micro wheel.

Right hand dominance

- The expression “right” handed is misleading
- Indicates that left hand is not used.
- Left hand is actually used for most real world tasks
- Right hand is therefore dominant.
- Too little research to conclude weather these principles transfer to individuals with left hand dominance.

Exceptions

- The strongest hand carries the load and the non dominant hand performs the key task of stabling the firewood

Applications to HCI

- Some two handed tasks can be performed using one hand, but with task decomposition overhead
- How do we identify what operations that should be designed for two handed operation
- Observe two handed task in the real world
- Characteristics to look for
  - Oscillation between repeated subtasks
  - Dependence of one subtask on the other (one task provides the frame of reference for the other)


That’s it!!!